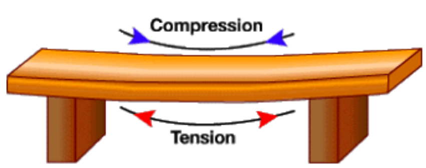
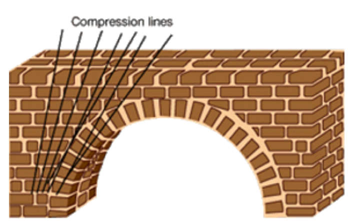
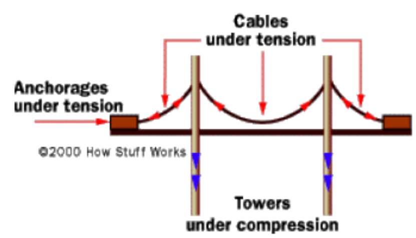
Forces in Bridges

Many people do not notice the different structures of bridges and may not realize how these different designs serve very specific purposes. Bridges require much more analyzing and decision making than many people realize. Often times, designers not only consider safety and practicality but also the appearance of the bridge and its aesthetical beauty.

Bridges are essential to our everyday life and possibly some of the oldest examples of engineering available. As early as 2000 years ago, the Romans built stone bridges to allow travel over bodies of water. Today, there are millions of bridges around the world that use different designs; however, they can be divided into three main categories – beam, arch, and suspension bridges. The main distinction between the three categories is the difference in span, or the distance between the columns or pillars of the bridge. The span will depend on how the compressive and tension forces are distributed in the structure of the bridge. Below you can see how these forces are distributed in the three types of bridges (pictures from How Stuff Works - Bridges):







The biggest difference between the three is the distances they can cross in a single span. A span is the distance between two bridge supports, whether they are columns, towers or the wall of a canyon. A modern beam bridge, for instance, is likely to span a distance of up to 200 feet (60 meters), while a modern arch can safely span up to 800 or 1,000 feet (240 to 300 m). A suspension bridge, the pinnacle of bridge technology, is capable of spanning up to 7,000 feet (2,100 m).

What allows an arch bridge to span greater distances than a beam bridge, or a suspension bridge to span a distance seven times that of an arch bridge? The answer lies in how each bridge type deals with two important forces called compression and tension:

- Compression is a force that acts to compress or shorten the thing it is acting on.
- Tension is a force that acts to expand or lengthen the thing it is acting on.

A simple, everyday example of compression and tension is a spring. When we press down, or push the two ends of the spring together, we compress it. The force of compression shortens the spring. When we pull up, or pull apart the two ends, we create tension in the spring. The force of tension lengthens the spring.

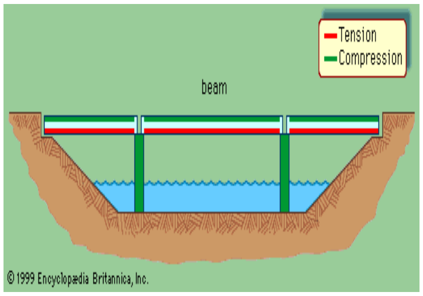
Compression and tension are present in all bridges, and it's the job of the bridge design to handle these forces without buckling or snapping. Buckling is what happens when the force of compression overcomes an object's ability to handle compression, and snapping is what happens when the force of tension overcomes an object's ability to handle tension. The best way to deal with these forces is to either dissipate them or transfer them. To dissipate force is to spread it out over a greater area, so that no one spot has to bear the brunt of the concentrated force. To transfer force is to move it from an area of weakness to an area of strength, an area designed to handle the force. An arch bridge is a good example of dissipation, while a suspension bridge is a good example of transference.

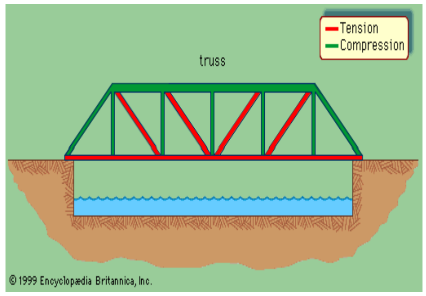
Types of Bridges

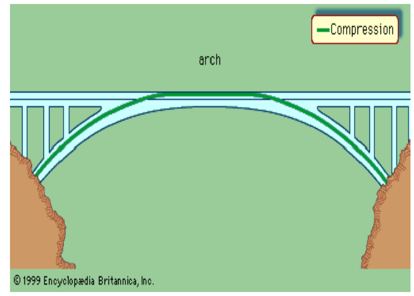
There are four major types of bridges:

Beam Bridge
Truss Bridge
Arch Bridge
Suspension Bridge

A **beam bridge** is the simplest of all types of bridges and consists of a horizontal structure with vertical supports at each end. When a load is applied to the structure, the lower part of the bridge is lengthened, or undergoes tension, while the upper part is squeezed, or undergoes compression. In the picture below you see the tension forces marked with red lines while the green lines represent compression forces.[2]





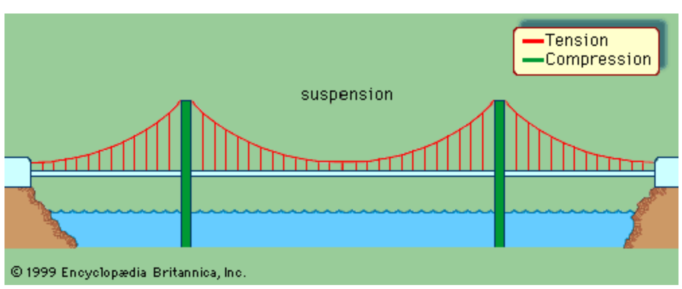


One major problem with beam bridges is that they have a tendency to bend in the middle when too much weight is applied. Also, beam bridges are no larger than 250 feet since the longer the length of the bridge, the weaker the vertical supports (piers) become which can lead to the collapse of the bridge.

A variation of the beam bridge is the **truss bridge**, which uses rigid triangles to spread out the compression and tension forces. Truss bridges are longer than simple beam bridges; however, they are still restricted in how long they can be since the longer the bridge the bigger and heavier the trusses are too.

An **arch bridge** has a semicircular structure with supports at both ends. Because the only forcing acting on the bridge is compression, arch bridges can support heavy loads easily and are longer than beam bridges.

Finally, a **suspension bridge** uses a series of cables that are hung from two towers. The cables in turn support the deck of the bridge. In suspension bridges, you have tension forces acting on the cables, and compression on the towers. Due to their unique design, suspension bridges can be up to 7000 feet in length, longer than any other type of bridge.



Questions: (answer on a separate piece of paper)

1. How is a tension force different from a compression force?
2. How does a compression force create a tension force?
3. What are the maximum spans for each bridge design? Why can't they exceed this amount?
4. What is the difference between buckling and snapping?
5. Compare and contrast the four major bridge designs based on forces and spans.